

Amendments to the Specification (where added material is shown in underlined type, deleted material is shown in ~~strikeout type~~.)

Please replace the paragraph starting on page 4, line 18 with following rewritten paragraph:

The present process avoids the difficult path of attempting to strip and capture the carbon dioxide from stack gases and without attempting to carry out separate chemical reactions of carbon dioxide to attempt to produce useful products. The process and system of the present invention uses unique gasification technology combined with fuel cells to generate electricity at high efficiency. This is accomplished by taking advantage of a very unique property of fuel cells - namely, the two anodic and cathodic reactions are separated by an electronically conducting membrane that keeps the product gases separate. In this way, a combustible feed gas can be fully oxidized in the first half-cell of the fuel cell without being commingled with the final products of the air reduction in the second half-cell electrode, i.e., N_2 . For example, in coal gasification, synthesis gas is formed consisting predominantly of hydrogen and carbon monoxide. This synthesis gas is fed into the first half-cell, i.e., the anode or negative terminal side, of the fuel cell, such as the solid oxide or molten carbonate types, where it is oxidized to water and carbon dioxide. These gases are not diluted by the typical nitrogen remaining after oxygen reduction in the second or remaining half-cell, i.e., the cathode side or positive terminal, of the fuel side. Nitrogen and combustion gases are commingled when combustion air is used in boilers or furnaces. Thus, in the fuel cell, the synthesis gas (syngas) is oxidized without being combusted with air and without being diluted by other gases. The fuel cell-produced water and carbon dioxide are simply separated from each other by condensing the liquid water and allowing the carbon dioxide to return to the gasifier. The carbon dioxide being injected into the high temperature gasifier undergoes a reaction with the high temperature carbonaceous feed to form more carbon monoxide, repeating the cycle.

Please replace the paragraph starting on page 5, line 13 with following rewritten paragraph:

By means of the present process and system, the carbon dioxide in the fuel cell is easily kept separate from the air side and any nitrogen. This carbon dioxide can be recycled back to the gasifier in nearly pure form. Likewise steam in pure form can be recycled as well in different amounts

under gasifier control system requirements to maintain the ideal hydrogen to carbon monoxide ratio in the range of about 1.2 to about 1.75. This steam helps maintain a high hydrogen content in the gasifier so that a portion of the gasifier-produced syngas can be used downstream in a chemical reactor such as a Fischer-Tropsch reaction system for the production of a variety of useful chemicals ranging from methanol to paraffin waxes. These in turn are used to make useful chemicals such as naphtha, gas oil, and kerosine, or agricultural chemicals or carbide abrasives. The latter are not ever burned in their lifecycle, and they sequester the carbon forever. Thus, the carbon monoxide is used to produce useful chemicals instead of discarding the valuable carbon source in the carbon dioxide. The carbon balance of the plant is maintained such that the mass of carbon input in the waste feed is equal to the carbon mass leaving the plant as valuable hydrocarbon products; not carbon dioxide.

Please replace the paragraph starting on page 6, line 1 with the following rewritten paragraph:

What has been achieved is a chemical plant merged with a power plant that produces useful hydrocarbon products, high efficiency electric power without substantially any carbon dioxide or other greenhouse gas emissions. And, most importantly gasification is much more flexible than a refinery or a coal boiler, since a wide variety of waste streams can be used as the feed material. Thus, this solves two serious problems.

Please replace the paragraph starting on page 6, line 6 with the following rewritten paragraph:

The process of the present invention is designed for use in an electric power producing plant using carbonaceous feedstocks such as coal, hydrocarbon oil, natural gas, petroleum coke, oil shale, carbonaceous-containing waste oil, carbonaceous-containing medical waste, carbonaceous-containing hazardous waste, other carbonaceous-containing ~~medical~~ waste, and mixtures thereof.

Please replace the paragraph starting on page 7, line 5 with the following rewritten paragraph:

FIGS. 9-10 show plots of the steam reforming of a mixture of a typical industrial waste and

fuel cell produced carbon dioxide at least about 20% added in the feed with ~~super-sub~~ sub-stoichiometric steam at 46-51% achieving high hydrogen and the cleanest syngas in accordance with the preferred embodiment of the present invention;

Please replace the paragraph starting on page 7, line 27 with the following rewritten paragraph:

Preferably gasifier 12 is a slightly inclined horizontal rotary kiln that is heated externally and is called an "indirectly heated rotary kiln." The slight inclination encourages the feedstock to move axially along the rotary kiln away from the inlet as it is rotated slowly. The carbonaceous feedstock or waste at or near room temperature is introduced into one end of the kiln where the temperature is at about 200°C and it is subjected to increasing temperatures as it moves along the length of the kiln toward the gas exit end. Preferably the temperature of the gas leaving the exit end is in the range of about 1100° to 1600°C (1650-2900°F). Preferably this can be done by pulling the exit gases through a superheater of the type shown in FIG. 11, which can be located in the region adjacent the exit end of the kiln shown in FIG. 12. The higher temperatures and added steam are needed to accomplish the high levels of destruction required by U.S. EPA law should there be hazardous waste contaminant in a waste feedstock. For recovery of metals and glass for possible recycling, these solids are removed from the kiln before they are melted. Preferably, these solids are removed from the rotary kiln at solids exit 14, which is at an appropriate location along the length of kiln where it is estimated that waste feed has reached a temperature of about 400°C (750°) and before the solids have melted.

Please replace the paragraph starting on page 9, line 7 with the following rewritten paragraph:

The oxidized syngas, ~~consisting essentially of hydrogen and carbon monoxide,~~ (consisting essentially of hydrogen and carbon monoxide) leaves anode 42 of fuel cell 26 mostly as water vapor and carbon dioxide. This stream of oxidized syngas passes via line 48 into air-cooled condenser 50, where the water vapor is condensed into liquid water and is removed from the condenser bottoms via line 52 for reuse. Wastewater recovered from a municipal sewage system can be used in gasifier 12. However, all or a portion of the

relatively pure water in line 52 can be sold or recycled and combined with the wastewater passing into gasifier 12 via line 38. The carbon dioxide gas is not condensed in condenser 50 and passes through into the condenser overhead as carbon dioxide gas to be fed back to the gasifier 12 via line 36. The carbon dioxide in high temperature gasifier 12 reacts therein with the carbonaceous feed material to form more syngas to further assist in the overall reaction. CO₂ or other greenhouse gases can be passed into gasifier 12 via line 56 and line 34 to maintain the desired H/C ratio of the feedstock.

Please replace the paragraph starting on page 10, line 1 with the following rewritten paragraph as follows:

In the Fischer-Tropsch catalytic reactor 30, the syngas in line 22 is reacted over a catalyst 70 to form higher boiling hydrocarbons, such as waxes or other useful hydrocarbon products recovered in line 76. These waxes, for example, can form a feedstock to a Shell Middle Distillates Synthesis Process where they are reacted to form naphtha, fuel gas, and kerosine, which are all valuable chemical products; see J. Eilers, S. A. Posthuma, and S. T. Sie, "The Shell Middle Distillate Synthesis Process (SMDS)," Catalysis Letter, 7, pp. 253-270 (1990). The pertinent portions of this paper ~~is~~ are incorporated by reference into this Detailed Description of the Invention.

Please replace the paragraph starting on page 10, line 22 with the following rewritten paragraph as follows:

The plots shown in FIGS. 2-10 are based on calculations performed by the method of the Gibbs Free Energy Minimization to yield gas compositions at thermodynamic equilibrium from the lowest temperature of 200°C up to 2000°C. The chemistry is started by placing methane (CH₄) and steam (H₂O) at one atmosphere in the gaseous state (subscript, g) in a vessel at 200°C. After waiting a sufficient amount of time, the compounds react slightly and form a small quantity of hydrogen (H₂) and carbon dioxide (CO₂) as shown in Fig. 2. This composition of the gas mixture is that which occurs if the chemical kinetics were fast enough to allow the reaction to reach completion in the time allotted. The following two reactions are occurring simultaneously:



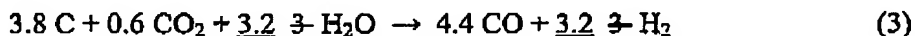


Please replace the paragraph starting on page 13, line 11 with the following rewritten paragraph as follows:

Unexpectedly, a much-preferred solution has now been discovered to optimize this fuel cell link that has been overlooked and not exploited previously. It involves using elevated steam feed and CO_2 simultaneously with complex waste streams that have higher carbon/hydrogen ratios than simpler compounds such as methane. This approach appears to be contrary to conventional wisdom and practice, which suggests that to achieve high ~~higher~~ hydrogen concentrations at high temperature, the worst option is to increase the carbon content of the feed. However, for carbon dioxide this simplistic logic has been found to be very wrong.

Please replace the paragraph starting on page 13, line 19 with the following rewritten paragraph:

The very simplified chemical reaction with the waste stream is fairly characterized entirely by carbon as in the following reaction:



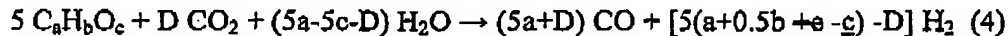
Please replace the paragraph starting on page 13, line 22 with the following rewritten paragraph:

Reaction (3) is already 68% 42.1% by volume hydrogen (i.e. mole percent), which is ~~far better than~~ comparable to the hydrogen levels in FIGS. 3-6. Therein, one would have expected about 46% by volume H_2 . Reaction (3) stoichiometry is the rough optimum, maximizing hydrogen content. Varying the stoichiometric quantities of the reactants produces less than optimum hydrogen. It is noteworthy that the addition of CO_2 to the feed can reduce ~~reduces~~ the requirements for steam below stoichiometric requirements. In fact, there is an optimum combination of using both CO_2 and steam.

Please replace the paragraph starting on page 14, line 1 with following rewritten

paragraph so that "+c" is "-c" in the chemical equation:

A generalized chemical reaction can be written for any carbonaceous feedstock, as expressed by the generalized empirical formula $C_aH_bO_c$:



Please replace the paragraph starting on page 14, line 9 with following rewritten paragraph so that "+c" is "-c" in the chemical equation:

Also, to help to adjust the H_2/CO ratio needed for Fischer-Tropsch synthesis of useful chemical co-products to sequester the carbon and avoid greenhouse gas emissions, examining this H_2/CO ratio is helpful, since it is expressed as:

$$\frac{H_2}{CO} = \frac{5(a + 0.5b -c) -D}{5a + D}$$

Please replace the paragraph starting on page 14, line 15 with following rewritten paragraph:

One notes for a given carbonaceous feedstock with the empirical formula, $C_aH_bO_c$, one can adjust the amount of CO_2 , "D", to satisfy the Fischer-Tropsch synthesis requirements for the products desired.

Please replace the paragraph starting on page 14, line 18 with following rewritten paragraph:

To achieve higher hydrogen concentrations at high temperature to drive the fuel cells, increased feedstock hydrogen content together with an excess steam ~~over~~below stoichiometric levels, $(5a-5c-D)$, is allowed and is combined with the recycled fuel cell carbon dioxide, D. As shown in Fig. 7-10, this provides the chemistry at thermodynamic equilibrium that achieves a high ~~higher~~ hydrogen-rich syngas that remains high and steady in hydrogen over a broad high temperature range up to and beyond $1300^\circ C$ without catalysts.

Please replace the paragraph starting on page 16, line 13 with the following rewritten paragraph:

Even further improvements can be made, unexpectedly, as are shown in FIG. 9, by increasing the $\text{CO}_2/\text{H}_2\text{O}$ ratio from the ~~1.3 in FIG. 7~~ about 1.0 in FIG. 8 up to 2.8 in FIG. 9. This added CO_2 from the fuel cell is 25% of the waste feed. The steam used in FIG. 8 is actually a decrease to 60% in the amount of steam consumption in the process, with the advantage of the steam-reforming reactor being able to accept more CO_2 , contrary to conventional thinking.